PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference PE4457	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/BR 02/00158	International filing date *(day/month/year)* 19.11.2002	Priority date *(day/month/year)* 19.11.2002
International Patent Classification (IPC) or both national classification and IPC F04B35/04		
Applicant EMPRESA BRASILEIRA DE COMPRESSORES S.A.-EMBRACO		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 12 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
02.12.2003	04.04.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Richmond, R Telephone No. +49 89 2399-2889

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/BR 02/00158

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1, 2	as originally filed
3-11	filed with telefax on 03.03.2005

Claims, Numbers

1-18	filed with telefax on 03.03.2005

Drawings, Sheets

1/4-4/4	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations

   see separate sheet

Cited Documents

1. Reference is made to the following document:

   D3: WO 02/077453 A

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

2. Document D3, which is considered to represent the most relevant state of the art, discloses a control circuit for a fluid pumping device from which the subject-matter of claim 14 differs in that a electrical control circuit is provided having a resistive element, a capacitive element, a piston-position sensor and a semiconductor device which effectively control the position of the piston preventing a collision between the piston and valves even under extreme load conditions.

   The technical problem solved by this distinguishing feature could be determined as to effectively control the position of the piston allowing it to advance to the maximum point of displacement using a simplified circuit without the need to employ a micro controlled circuit.

   The solution as defined by the combination of features in claim 14 appears to be not known from document D3 or from any of the documents cited in the international search report and does not appear to be rendered obvious by any of these documents alone or in combination, and is not considered a matter of normal design proceedure.

   The subject-matter of claim 14 is therefore new (Article 33(2) PCT).

3. Independant claim 1 appears to comprise of all the features of claim 14 with the additional feature of a trigger point delay, and is therefore also new (Article 33(2) PCT).

4. For the same analogous reasons as given under item 1 the subject-matter of independant method claim 10 is also considered new (Article 33(2) PCT).

5. Claims 2-9,11-13,15-18 are dependent on claims 1,10 or 15 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII
Certain defects in the international application

6. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D3 (now considered the closest prior art) is not mentioned in the description, nor is this document identified therein.
In addition the background art PI 9907432-0 cited in the description cannot be retreived, and is not recited with the correct patent number. Furthermore the cited document US-A-5 704 711 appears not relevant to subject-matter of the application.

Re Item VIII
Certain observations on the international application

7. Although claims 1 and 14 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.
Claim 1 comprises of all the features of claim 14 and is therefore not appropriately formulated as a claim dependent upon the latter (Rule 6.4 PCT).

8. In claim 14 the expression "... refeeding an outlet and an inlet (G) of the latter..." causes confusion as to which the "latter" refers to (Article 6 PCT).

9. The expression "...in a fluid device..." used in claim 1 is unclear because the term "in" introduces ambiguity. It is unclear as to exactly for what the protection is sought (Article 6 PCT).

piston. This deviation from the middle point of the oscillatory movement is proportional to the difference in pressure between the discharge and the suction.

For the above reasons, in this situation, it is necessary to control the course of displacement of the piston by means of a device that controls the voltage imposed on the linear motor, re-fed by the information of piston position, basically estimated on the basis of the information about the current supplied to the motor and the voltage induced in the motor terminals. Solutions like this are described in documents US 5,342,176, US 5,496,153, US 5,450,521, and US 5,592,073.

Another solution for controlling the movement of the piston is described in document PI 9907432-0. According to the solution described therein, a monitoring system is foreseen for monitoring the times the piston passes by a determined reference point within the compressor. In this way, when the residence time of said piston beyond the reference point exceeds a pre-established value, the voltage level is momentarily reduced during the respective movement, thus avoiding a collision with the valve plate.

Further according to another technique described in document JP 11336661, the movement of the piston is controlled by counting discrete points thereof along the cylinder of the compressor. In case the piston moves excessively, the value of the average voltage applied to the respective motor is reduced so as to decrease the movement amplitude of said piston.

Another way adopted to provide re-feeding to this voltage controller is to observe whether the piston collides with the valve plate. Such a collision is detected by means of a microphone or accelerometer, which generates a command for reducing the voltage applied to the motor and consequently the course of displacement of the piston.

Objectives of the Invention

The objective of the invention is to control stroke course of displacement of the piston of a linear compressor or of any fluid-pumping device, such as piston-actuated water pumps, allowing the piston to advance as far as the end of its mechanical course of displacement, even in extreme load

conditions, without allowing the piston to collide with the valve system.

It is also an objective of the present invention to control the course of displacement of the piston of a linear compressor or of any fluid-pumping device, allowing the piston to advance as far as the end of its mechanical course of displacement, even in extreme load conditions, without allowing the piston to collide with the valve system, even in the presence of external disturbances of the power-feeding network.

Another objective of the present invention is to provide control over the course of displacement of the piston of a linear compressor or any other fluid-pumping device, without the need for information about the displacement of the middle point of oscillation of the piston.

A further objective is to provide control over the amplitude of the course of oscillation of a linear compressor or any fluid-pumping device, allowing control over the cooling capacity developed by the compressor.

Also other objectives of the present invention are to obtain a control system that meets the objectives of the present invention, that is easy to implement on an industrial scale and that has a low unit cost of manufacture and replacement, and to obtain a system that is self-fed, dispensing with the use of an additional external source, and that still has a low consumption of electric energy.

Brief Description of the Invention

In order to achieve the objectives of the present invention, a control system is foreseen for controlling the movement of a piston in a fluid-pumping device, the piston being displaceable in a block of the fluid-pumping device and being driven by a motor fed by a voltage. The system comprises a semiconductor electronic device that cyclically applies the voltage to the motor for driving the piston, a resistive element, a capacitive element, a piston-position sensor for indicating the passage of the piston by a point at the block of the fluid-pumping device, the capacitive element being charged by means of the resistive element at each cycle of application of voltage to the motor, the capacitive element being discharged at least partly when the piston passes by said point.

Further according to the present invention, the objectives are achieved by a method of controlling the movement of a piston in a fluid-pumping device, the piston being displaceable in a fluid-pumping device and being driven by a motor fed by a voltage. This method comprises the steps of: charging a capacitive element by means of a resistive element; monitoring the movement of the piston by means of a position sensor; maintaining the charge level of the capacitive element until the position sensor has detected the passage of the piston by a predetermined point at the compressor block; and discharging the capacitive element at least partly.

Further according to the teachings of the present invention, these objectives are achieved by means of a fluid-pumping device comprising a piston displaceable in a block, the piston being driven by a motor fed by a voltage. This device comprises a circuit having a semiconductor electronic device, a resistive element, a capacitive element, a piston-position sensor for indicating the passage of the piston by a point at the compressor block. The resistive element and the capacitive element are associated to the semiconductor electronic device, re-feeding an outlet and an inlet of the latter, the capacitive element being charged by means of the resistive element and being discharged at least partly when the piston passes by said point.

Brief Description of the Drawings

The present invention will now be described in greater detail with reference to one of the embodiments represented in the figures, in which

- Figure 1 shows a linear compressor schematically;
- Figure 2 illustrates the curves of piston displacement and the voltage on the linear motor provided with the control system of the present invention;
- Figure 3 illustrates a control system for controlling the position of the piston of a linear compressor according to a first embodiment of the present invention; and
- Figure 4 illustrates a control system for controlling the position of the piston of a linear compressor according to a second embodiment of the present invention;

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- Figure 5 illustrates the behavior of the signals generated by the bidirectional start switch and the time relationship of these signals with the voltage of the circuit branch that contains the capacitor Cy.

Detailed Description of the Figures

As can be seen in figure 1, a linear compressor 1 basically comprises a piston 10 that is displaced in oscillatory motion within the block 5, so as to compress a gas that is charged and discharged through a valve plate 11, which comprises a charge valve 13 and a discharge valve 12.

Typically, an elastic means such as a spring 4 is associated with the piston 10, so that the latter can have a resonant movement within the block 5 of the compressor 1.

The movement of the piston 10 is induced by a linear-type motor 2, which in turn is driven by an electric voltage V, which should be controlled in order to prevent the piston 10 from colliding with the plate 11.

Although the figures illustrate a linear compressor, the object of the present invention is applicable to any fluid-pumping device 1, as for example a water pump. For this purpose, one should only to take into consideration the constructive differences between such devices.

The methods of controlling the movement of the piston 10 employed in earlier techniques include monitoring motion times of the piston by means of microcontrolled circuits. The times to be monitored include: (i) residence time "t_o" of the piston 10 beyond a point R that is physically defined in its course of displacement, and this point is close to the end of the maximum course of displacement M possible to the piston 10, (ii) the time "t_c" of duration of the complete cycle, (iii) the time "t_{om}" corresponding to the maximum course of displacement M possible to the piston 10. The average voltage V_m applied to the motor 2 is incremented, if the time "t_o" is shorter than the desired time "t_{od}", and vice-versa. And the desired displacement "P" is maintained for supplying a determined cooling capacity (see figure 2).

The point M is very close to the valve plate 11, being typically at a distance of some dozens of micrometers, while the point R is located close to the valve plate 11, being typically at a distance of from 1 to 2 millimeters, a

distance sufficient to avoid collision of the piston 10 with said plate 11.

According to the present invention, and on the basis of the above-cited information about the behavior of the piston 10, one may replace the microcontrolled control systems by passive control circuits, thus reducing the manufacture costs thanks to the low cost of the pieces, maintenance by low consumption of electricity.

Particularly, according to the present invention, one foresees a re-feed (or self-fed) electronic circuit 30, 40 that alters the amplitude of the course of displacement of the piston 10, with the same approach employed in other systems that are controlled by microcontrollers, but without the need for monitoring the cited times.

Thus, according to the present invention, the detection of the passage of the piston by the defined physical point R may be effected by some type of physical sensor S installed inside the compressor 1, be it of the contact, optical or inductive or any other type (see figure 3, in this case). However, this detection may also be effected by adding a magnetic disturbance to the voltage present in the terminals of the motor 2, this disturbance being created, for example, by a constructive detail of the magnetic circuit of the motor. This is the case of the construction of the circuit 40, figure 4.

According to two preferred solutions described here, the position sensor S may comprise the circuits 30, 40 illustrated in figure 3 and 4, which include a position sensor S_p by direct contact and a position sensor L_s by inductive sensor, respectively, and which can effect the control automatically, without the need to employ a microcontrolled circuit.

The control system and method are carried out by means of a tiristor semiconductor device or bidirectional power switch T, which cyclically applies an electric voltage V to the motor L. The trigger circuit G (gate or inlet G) of this switch T is actuated by means of the position sensor Sp, Ls, which sends a signal that generates the angle of triggering said switch T, this signal causing a retardation time proportional to the discharge level of the capacitor Cy. The gate circuit G connected to the capacitor Cy, sends a voltage signal to the linear motor 2 for a longer or shorter time, for the purpose of adjusting

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the cooling capacity of said linear compressor 1.

Figure 5 illustrates the wave shape of the voltage V applied to the motor 2 and the stretches where the semiconductor device T does not conduct, as well as the wave shape of the current I.

As can be seen in figures 1, 3, and 4, according to the teachings of the present invention, the capacitor Cy is associated to the semiconductor device T, so that it will be associated between – and re-fed – the outlet S_G and the inlet G of the latter, and also in association with the switch S, which indicates the passage of the piston by the point R.

Figure 5 illustrates how this solution interferes with the voltage level V of the inlet of the motor L_m. Raising the voltage in the branch of the capacitor Cy (see stretch A in figure 5) is a function of the capacitance values of the Cy and Cx and of the resistance R_B. In this way, it is possible to adjust the circuit 30, 40 to varied constructions of the compressor 1, so that the semiconductor electronic device T can be adequately triggered (see stretch A' in figure 5, where the semiconductor T conducts).

The discharge velocity of the capacitor Cy is a function of the capacitance values of Cy, Cx and of the resistance values of R, R_T (see stretch B of the curve in figure 5), which should be designed in an adequate way, so that the triggering of the electronic device T will occur in an adequate way.

As can be seen in figure 3, a first preferred embodiment of the movement-control system includes the circuit 30, which comprises a position sensor Sp constituted by an electromechanical switch that is directly driven by the piston 10 when the latter passes by the point R, resulting in alteration of operation of the semiconductor electronic device T.

In this embodiment, in order to trigger the semiconductor electronic device T through the respective gate, the capacitor Cy is charged by means of the resistance Rb up to a level Vb (threshold voltage of the transistor T_2), and remains in this state until the course of displacement of the piston 10 reaches the point R, where the position sensor Sp will close contact (see Sp = On in figure 5) for a short period of time and will discharge partly. The capacitor Cy, in the next semicycle, will cause the semiconductor elec-

tronic device T to enter with some delay, as may be inferred from the deformation of the voltage curve V at the point 23, illustrated in figure 2 (see also figure 3).

The residence time at zero level (or a sufficiently low level in the winding Lm of the motor 2, so that the latter will not operate) of voltage V will depend upon the time during which the contact of the position sensor Sp has remained closed and upon the value of Ri + Rt (for example, a thermostat). The values Ri + Rt should be such, that when Rt is at the condition of maximum resistance and the piston 10 reaches the point M, the capacitor Cy will be discharged at such a level, that the semiconductor electronic device T will not be triggered in the next semicycle.

According to a second preferred embodiment of the present invention, and as may be seen in the system 40 illustrated in figure 4, the sensor S is carried out by means of a sensor or inductive element L_i.

In this embodiment, the sensor Li detects (see Li = On in figure 5) the passage of the piston 10, causing the transistor T_2 to start conducting, discharging at least partly the capacitor Cy and actuating in a way analogous to that of the first preferred embodiment of the present invention.

As may be seen in figures 3 and 4, the circuits 30, 40 are self-fed and, therefore, they dispense with the use of an external feed source, which reduces the costs of manufacture and maintenance.

Further, the transistor T_1 closes the circuit in the two embodiments, so as to trigger the electronic device T, actuating as a bidirectional switch: now charging the capacitor Cy, now discharging it.

Since this is a self-fed circuit 30, 40, the present invention brings about, as an advantage, the possibility of dispensing with the use of an external feed source, in addition to resulting in a low consumption of electricity (in the milliamperes range) and in addition to enabling the replacement thereof in the event of a failure.

In order to implement the application of the systems described above, the present invention also foresees a method for controlling the movement of a piston 10 in a linear compressor 1 or any other fluid-pumping

device 1. This method comprises the steps of:

- charging the capacitive element Cy by means of the resistive element R_b,

- monitoring the movement of the piston 10 by means of the position sensor S;

- maintaining the charge level of the capacitive element Cy until the position sensor S has detected the passage of the piston 10 by the point R, and

- discharging, at least partly, the capacitive element Cy.

Once the discharging step is finished, the capacitive element Cy is again charged, as may be seen in figure 5.

It is also an objective of the present invention to construct a fluid-pumping device 1, provided with the system for controlling the movement of the piston 10, to prevent the latter from bumping into the valve plate 11.

Thus, according to the present invention and to its teachings, collision of the piston 10 with the valve plate 11 may be avoided. The intermediate situations will serve as a control over the capacity of the compressor 1.

The system and method of the present invention enable one to estimate, at each cycle, the oscillation amplitude of the piston 10 much more precisely, enabling the electronic control to react for compensating the variations in the cooling capacity (in the case of application in compressors), which are slow variations, maintaining the average amplitude of the course of oscillation of the piston 10 at the desired value and equal to P. This system and method also enables rapid reactions of the electronic control for compensating shape variations in the operation conditions caused by fluctuations in the feed voltage, and these corrections should be imposed at each oscillation cycle, so as to correct the amplitude of the stroke of the piston 10 in the final portion of its path, after passing by the physical reference point R.

The system and method of the present invention result in the advantage of a rapid reaction, with corrections at each cycle, without the need for estimates based on the voltage and current imposed on the motor 2, and

without mistakes due to secondary variables such as temperature, the construction of the motor 2 and the displacement of the middle point of oscillation of the piston due to the average difference in pressure between the faces 8, 9 of the piston 10.

The present invention enables one to implement an effective control over the course of displacement of the piston 10, independently of the required cooling capacity, whereby one can prevent the piston 10 from bumping against the valve plate 11, even in the presence of rapid disturbances caused by the natural fluctuation of the voltage in the commercial network of electric energy.

Preferred embodiments having been described, it should be understood that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, which include the possible equivalents.

CLAIMS

1. A control system for controlling the movement of a piston (10) in a fluid-pumping device (1), the piston (10) being displaceable in a block (5) of the fluid-pumping device (1) and being driven by a motor (2) fed by a voltage (V), the system being characterized by comprising:

- a semiconductor electronic device (T) applying cyclically the voltage (V) to the motor (2) to drive the piston (10);
- a resistive element (Rb);
- a capacitive element (Cy);
- a piston-position sensor (S) to indicate the passage of the piston (10) by a point (R) at the block (5) of the fluid-pumping device (1);
- the capacitive element (Cy) being charged by means of the resistive element (Rb) at each cycle of application of voltage (V) to the motor (2), the capacitive element (Cy) being discharged, at least partly, when the piston (10) passes by the point (R).

2. A control system according to claim 1, characterized in that the semiconductor electronic device (T) is self-fed by the voltage (V).

3. A control system according to claim 1 or 2, characterized in that the semiconductor electronic device (T) comprises an actuation inlet (G) and an outlet (S_G), the resistive element (Rb) and the capacitive element (Cy) being associated with the semiconductor electronic device (T), re-feeding the outlet (S_G) with the inlet (G).

4. A control system according to claim 1, 2, or 3, characterized by additionally comprising a triggering semiconductor electronic device (T_1) associated with the inlet (G) and with the capacitive element (Cy) and resistive element (Rb).

5. A control system according to any one of claim 1 to 4, characterized in that the electronic device comprises a bidirectional power switch (T).

6. A control system according to any one of claim 1 to 5, characterized in that the sensor (S) is associated with the entry (G) of the device

(T).

7. A control system according to claim 6, characterized in that the device (T) is actuated by a semiconductor electronic device (T1).

8. A control system according to claim 7, characterized in that the position sensor (S) includes a contact element (Sp) for contact with the piston (10).

9. A control system according to claim 8, characterized in that the position sensor (S) includes an inductive element (Li).

10. A control system according to claim 9, characterized in that the inductive element (Li) is associated with a semiconductor device (T_2).

11. A method of controlling the movement of a piston (10) in a fluid-pumping device (1), the piston (10) being displaceable in a block (5) of the fluid-pumping device (1) and being driven by a motor (2) fed by a voltage (V), the method being characterized by comprising the steps of:

- charging a capacitive element (Cy) by means of a resistive element (Rb),

- monitoring the movement of the piston (10) by means of a position sensor (Sp, Li),

- maintaining the charge level of the capacitive element (Cy) until the position sensor (Sp, Li) has detected the passage of the piston (10) by a predetermined point (R) at the block (5), and discharging, at least partly, the capacitive element (Cy).

12. A method according to claim 11, characterized in that, after the step of discharging, the capacitive element (Cy) is again charged.

13. A method according to claim 11 or 12, characterized in that, in the step of monitoring the movement of the piston (10), a contact element (Sp) is actuated.

14. A method according to claim 11 or 12, characterized in that, in the monitoring step, an inductive element (Li) is actuated.

15. A fluid-pumping device (1) comprising a piston (10) displaceable in a block (5), the piston being driven by a motor (2) fed by a voltage (V), the device (1) being characterized by comprising:

- a circuit (30, 40) having a semiconductor electronic device (T), a resistive element (R_B), a capacitive element (Cy) and a piston-position sensor (S) to indicate the passage of the piston (10) by a point (R) at the block (5);

- the resistive element (R_B) and the capacitive element (Cy) being associated with the semiconductor electronic device (T), re-feeding an outlet and an inlet (G) of the latter;

- the capacitive element (Cy) being charged by means of the resistive element (Rb) and being discharged, at least partly, when the piston (10) passes by the point (R).

16. A device according to claim 15, characterized in that the circuit (30, 40) is self-fed.

17. A device according to claim 15 or 16, characterized in that the electronic device comprises a bidirectional power switch (T).

18. A device according to claim 15, 16, or 17, characterized in that the position sensor (S) includes a contact element (Sp) for contact with the piston (10).

19. A device according to claim 15, 16, or 17, characterized in that the position sensor (S) includes an inductive element (Li).